



Nanocrystal Solar Cells: New Shapes and Opportunities

Tetrapods for higher efficiency solar cells and license announcement

Following the demonstration of near-class-record efficiencies for hybrid organic/semiconductor nanocrystal solar cells (MSD Highlight 02-1), the research group of A. P. Alivisatos has developed new nanocrystal shapes that have the promise to increase further the cells' efficiencies. Nanosys, Inc. has obtained an exclusive license from LBNL for commercial development of this new solar cell technology.

Researchers in LBNL's Materials Sciences Division are designing and fabricating a new generation of high-efficiency solar cells that combine the advantages of inorganic semiconductor-based cells with the ease of fabrication of plastics. This technology is based on the careful design and synthesis of nanosized semiconductor particles with control of their composition, size, and shape and the development of new methods to integrate the nanoparticles into polymer matrices (plastics) to form optimally functional cells. Successful completion of this work could drastically reduce the cost of solar cells and enable their incorporation as low cost components into consumer products.

Previously, power conversion efficiencies of up to 1.7% were demonstrated for hybrid nanocrystal/polymer cells in which the size and aspect ratio of cadmium selenide (CdSe) nanorods were controlled to optimize cell performance. While below the 10% values achieved for amorphous Si solar cells or the nearly 30% achieved for the most advanced single crystal devices, this value compares very well to those achieved by the best polymer devices (ca. 2.5%).

Two new breakthroughs are reported here that should improve cell efficiency even further. In the first, methods were developed to obtain suitably sized cadmium telluride (CdTe) nanocrystals. CdTe absorbs more of the "colors" of sunlight than does cadmium selenide, which should lead to a 30% improvement in power efficiency based solely on improved absorption. In second breakthrough, a reproducible synthesis method that forms four-armed nanotetrapods of CdTe with excellent control over their size was developed. The new synthesis method exploits the existence in some materials of two or more crystal structures in different domains of the same crystal (polytypism). In the case of CdTe, the temperature was carefully chosen such that one structure ("zincblende") could be made to nucleate initially (but not grow rapidly). Under these conditions, a second phase ("wurtzite") had a higher growth rate. Subsequent growth of the wurtzite phase on the zinc-blende "seed" produces a tetrapod shape (see figure). By changing the reaction conditions, the width and length of the four arms can be independently controlled.

The tetrapod shape can be tuned to optimize solar cell efficiency. The "quantum confinement" effect that makes the electronic properties of nanocrystals size-dependent was found to be strongly affected by the diameter of the arms (and less so by the length of the arms). As shown in the figure, the band gap could be tuned from 1.8 eV to 1.6 eV by varying the arm diameter. In addition, the inherent characteristic of a tetrapod to self-align on a substrate with one arm always pointing towards one electrode should improve the fabrication yield of hybrid nanocrystal-polymer solar cells.

The potential commercial value of LBNL's nanocrystal solar cell technology has been recognized by industry. Nanosys has obtained worldwide, exclusive rights to LBNL's nanocomposite solar technology and materials. Combined with \$38 million in new financing and a recent partnership with Matsushita Electric Works, Nanosys intends on bringing LBNL's new technology to market. One of the initial goals of the company is to further increase the efficiency of the system.

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L. Manna, D. J. Milliron, A. Meisel, E. C. Scher, and A. P. Alivisatos, "Controlled growth of tetrapod-branched inorganic nanocrystals," *Nature Materials* 2, 283 (2003).